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Effects of Passive Head-and-Neck Movements on the Performance of i-gel® Supraglottic Airway Device in Anesthetized Patients – A Randomized Crossover Trial

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Abstract

Background: Passive movements of head and neck are sometimes unavoidable during surgery under general anesthesia due to patient positioning according to the needs of the surgery or transmitted movements from surgical manipulations. **Aims:** This prospective crossover randomized study evaluates the effects of passive movements of the head and neck on the performance of i-gel® supraglottic airway device in spontaneously breathing patients under general anesthesia. **Materials and Methods:** Sixty spontaneously breathing patients on pressure support ventilation with positive end-expiratory pressure (PEEP) under general anesthesia were randomized to seven sequences of passive head-and-neck movements with i-gel® *in situ*. After steady state of general anesthesia was achieved and maintenance with sevoflurane in N_2O and O_2 was reached, the passive head-and-neck movements were done. Peak airway pressure, exhaled minute volume, end-tidal carbon dioxide ($ETCO_2$), oxygen saturation, audible leak of airway gases, and visible outward displacement of the i-gel® were recorded in the neutral position and with each passive head-and-neck movement. Paired continuous data were analyzed by Friedman rank sum test with paired Wilcoxon signed-rank test. Paired nominal data were analyzed by Cochran's Q test with pair-wise McNemar test. **Results:** Extension, right or left lateral flexion, and right or left rotation of the head and neck resulted in significant reduction in the exhaled minute ventilation, rise in $ETCO_2$, and leak of airway gases compared to the neutral position ($P < 0.05$). Flexion movement did not cause significant changes in the exhaled minute ventilation, rise in $ETCO_2$, and audible leak of airway gases as compared to the neutral position. **Conclusions:** Ventilatory performance of the i-gel® deteriorates upon extension, right or left lateral flexion, and right or left rotation of the head and neck in spontaneously breathing patients under general anesthesia on pressure support ventilation with PEEP.

Keywords: General anesthesia, passive head-and-neck movement, pressure support ventilation with positive end-expiratory pressure, spontaneous breathing, supraglottic airway

Introduction

Supraglottic airway devices (SADs) are widely used to maintain an open airway in patients under general anesthesia for nonhead-and-neck surgeries, surgeries in nonprone position, and nonfull-stomach patients. I-gel® is a second-generation SAD with several advantages over the classic laryngeal mask airway (cLMA). Inhalation general anesthesia with spontaneous breathing on pressure support ventilation with positive end-expiratory pressure (PEEP) with SAD is a convenient and popular anesthetic technique for a vast number of patients undergoing limb surgeries, superficial surgeries of the torso, and gynecological surgeries. Passive movements of the head and neck under general anesthesia can lead to displacement of the SAD even if the device is secured to the face of the patient with adhesive tapes. Displacement of an SAD from its initial position can lead to the deterioration of its performance and can compromise the airway of the patient under general anesthesia. Passive movements of head

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and neck are sometimes unavoidable during surgery under general anesthesia due to patient positioning according to the needs of the surgery or transmitted movements from surgical manipulations. The effects of passive movements of the head and neck on the performance of i-gel® in spontaneous breathing adults on pressure support ventilation with PEEP under general anesthesia have not been studied prospectively till date. The purpose of this study was to compare the performance of i-gel® in neutral position and six different passive movements of head and neck, in spontaneous breathing adults on pressure support ventilation with PEEP under general anesthesia. Our null hypothesis stated that there shall be no significant change in the performance of the i-gel® with passive head-and-neck movement within the normal range of movement. Our alternate hypothesis stated that the performance of the i-gel® in any other position of head and neck shall not be equal to that in the neutral position.

Materials and Methods

This single-center, prospective, randomized crossover study was approved by the Institutional Ethics Committee for Human Research (ECR/287/Inst/WB/2013). The study was registered prospectively with the Clinical Trials Registry of India (CTRI) on December 9, 2014, with Clinical Trial Registration No. CTRI/2014/12/005266. Written informed consent was obtained from patients aged 18–65 years, both male and female, those with American Society of Anesthesiologists (ASA) physical Status I and II, and those undergoing general anesthesia with i-gel® for elective surgical procedures. Exclusion criteria were as follows: unwilling patients, patients with ASA III or worse physical status, those with any contraindications to the use of SAD, those with a history of trauma or surgery or any diseases involving atlanto-occipital joint or cervical spine, or those with any restriction in active range of movement of head and neck on preoperative physical examination. The sequences of passive head-and-neck movement were randomly allocated to each participant using computer-generated random numbers. The passive range of movements of the head and neck was measured by a universal goniometer.

Sample size

This is a randomized crossover study with the exhaled minute ventilation as the primary outcome measure. The null hypothesis stated that there is no difference in the mean exhaled minute ventilation in the neutral position to that in the other positions. The alternate hypothesis stated that the mean exhaled minute ventilation with any passive movement is not equal to that in the neutral position. Prior pilot study showed an effect size of 0.44 (calculated from the mean and standard deviation of exhaled minute ventilation in neutral position and extension of head and neck). To correctly reject the null hypothesis with a power of 95%, alpha error of 5%, and using one-tailed Wilcoxon signed-rank test (matched pairs), sixty participants were required. The sample size was calculated using the free and open-source software G * Power[1] version 3.1.8 31 released on January 2014.

Study protocol

Seventy-eight patients were screened during preanesthesia checkup for eligibility of enrollment in the study. Sixty-nine patients were eligible and were offered the study-related information verbally and in written form. Five patients were not willing to participate in the study. The willing participants were requested to give consent for participation in the study. Four patients underwent general anesthesia with tracheal intubation and not included in the study. Sixty patients were randomized in the study after obtaining their written informed consent [Figure 1]. General anesthesia under standard monitoring was induced with intravenous 2 $mg.kg^{-1}$ propofol injection. Once jaw relaxation was confirmed under anesthesia, the airway was secured with appropriate-sized i-gel® according to the actual body weight of the patient (size 3 for 30–60 kg, size 4 for 50–90 kg, and size 5 for >90 kg). Anesthesia was maintained with 1.5 minimum alveolar concentration (MAC) sevoflurane in 50% N_2O and 50% O_2 (fresh gas flow O_2 1 $L.min^{-1}$, N_2O 1 $L.min^{-1}$), with spontaneous breathing on pressure support ventilation (flow trigger 1 $L.min^{-1}$, support pressure 10 cmH_2O or 1 kPa, and PEEP 4 cmH_2O or 0.4 kPa), with a circle breathing system and a circle absorber. Pressure support was adjusted to maintain normocarbia (end-tidal carbon dioxide [$ETCO_2$] between 35 and 40 mmHg, i.e., 4.7–5.3 kPa) in the steady state. No further change or adjustments of flow trigger, pressure support, PEEP, sevoflurane concentration, or fresh gas flow were done during or after each passive head-and-neck movement and the subsequent period of observation. The seven permutation sequences of neutral and passive head-and-neck movements were as follows: N, F, E, Lf, Rf, Lr, and Rr; F, E, Lf, Rf, Lr, Rr and N; E, Lf, Rf, Lr, Rr, N, and F; Lf, Rf, Lr, Rr, N, F, and E; Rf, Lr, Rr, N, F, E, and Lf; Lr, Rr, N, F, E, Lf, and Rf; Rr, N, F, E, Lf, Rf, and Lr, where N = neutral, F = flexion of 40°, E = extension of 40°, Lf = left lateral flexion of 40°, Rf = right lateral flexion of 40°, Lr = left rotation of 40°, and Rr = right rotation of 40°. These sequences were randomly allocated to the participants using computer-generated random numbers. After each

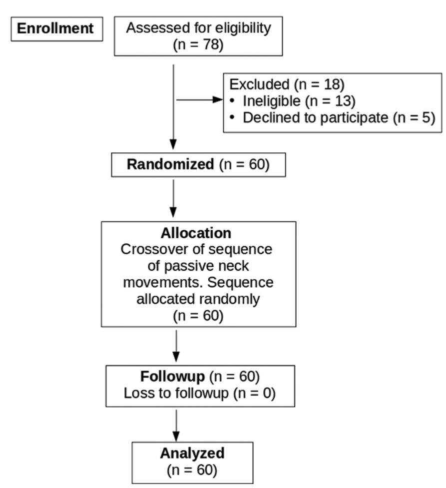

Figure 1: CONSORT diagram representing the enrollment process of the study participants

intervention, the head-and-neck position was returned to neutral position and i-gel® was re-positioned to its initial insertion depth. This was done to minimize the occurrence of any "carry-over effects" after each intervention. The participants were blinded due to general anesthesia. Although the observers were not blinded, there was little opportunity for observer bias. The primary outcome measures – exhaled minute volume and $ETCO_2$ – were measured accurately by the ventilator's spirometer of anesthesia workstation and the anesthesia monitor (side-stream capnography of gas module), respectively.

Measurements

Demographic characteristics (age, sex, height, weight, body mass index, and ASA physical status), size of i-gel®, pressure support, and PEEP in steady state were recorded for each participant. All the passive movements of the head and neck were done by measurement with a universal goniometer. Once steady-state 1.5 MAC sevoflurane was achieved, the following parameters were recorded with the head and neck in neutral position:

a. Peak airway pressure measured by the spirometer of the anesthesia workstation
b. Exhaled minute volume measured by the spirometer of the anesthesia workstation
c. $ETCO_2$ measured by side-stream capnography of the anesthesia patient monitor
d. SpO_2 measured by pulse oximetry on the anesthesia patient monitor
e. Leak of airway gases around i-gel® (audible leak): Yes/no
f. Visible outward displacement of the i-gel® supraglottic airway: Yes/no.

The following parameters were recorded 1 min after each passive head-and-neck movement, i.e., (a) flexion of 40°, (b) extension of 40°, (c) left lateral flexion of 40°, (d) right lateral flexion of 40°, (e) left rotation of 40°, and (f) right rotation of 40°.

a. Peak airway pressure measured by the spirometer of the anesthesia workstation
b. Exhaled minute volume measured by the spirometer of the anesthesia workstation
c. $ETCO_2$ measured by side-stream capnography of the anesthesia patient monitor
d. SpO_2 measured by pulse oximetry on the anesthesia patient monitor
e. Leak of airway gases around i-gel® (audible leak): Yes/no
f. Visible outward displacement of the i-gel® supraglottic airway: Yes/no.

Statistical analysis

Continuous data were subjected to Shapiro–Wilk test of normality. Repeated-measures data of the performance parameters of i-gel® after each movement with that of the neutral position were measured by Friedman rank-sum test. *Post hoc* analysis between pairs of repeated measures was done by paired Wilcoxon signed-rank test. The null hypothesis for this study states that there is no difference in the performance of i-gel® with any passive movement as compared to that in the neutral position. An alternate hypothesis states that the performance of i-gel® with any passive movement is not equal to that in the neutral position. Paired nominal data (incidence of audible leak of airway gases and visible displacement of the i-gel®) were compared by Cochran's Q test. *Post hoc* analysis of nominal data between pairs of nominal data was done by the pair-wise McNemar test. $P < 0.05$ was considered statistically significant for the Friedman rank-sum test, Wilcoxon signed-rank test, Cochran's Q test, and McNemar test. Statistical analysis was done using a free and open-source statistical software Rstudio Version 1.3.959 © 2009–2020 RStudio PBC, 250 Northern Ave, Boston, MA 02210, USA. Within RStudio, two specific R packages were used: (a) Rcmdr package version 2.6-2, for descriptive statistics, and Friedman rank sum test with post hoc analysis, (b) RVAideMemoire package version 0.9-77 for Cochran Q test with post hoc analysis.

Results

The demographic characteristics of the study population are described in Table 1. It was observed that all continuous data (except height) were nonnormally distributed (Shapiro–Wilk test of normality, $P < 0.05$). Hence, the continuous data were expressed as median and interquartile range. Friedman's rank-sum test comparing medians of exhaled minute volume in neutral, flexion, extension, left flexion, right flexion, left rotation, and right rotation positions showed a statistically significant difference ($P < 0.05$). *Post hoc* analysis between pairs of median exhaled minute volumes was done by paired-sample, two-sided, Wilcoxon signed-rank test with continuity correction. Friedman's rank-sum test comparing medians of $ETCO_2$ in neutral, flexion, extension, left flexion, right flexion, left rotation, and right rotation positions showed a statistically significant difference ($P < 0.05$). *Post hoc*

Table 1: Demographic characteristics of the study population

Parameter	Mean (SD)	Median (IQR)
Age (years)	37.8 (15.8)	35 (26.5)
Height (cm)	154.1 (4.1)	154.0 (6.0)
Weight (kg)	49.2 (8.6)	48 (9.3)
BMI ($kg.m^{-2}$)	20.7 (3.6)	20.9 (4.2)
Sex		
Male	44	
Female	16	
ASA physical status		
I	50	
II	10	
i-gel® size		
Size 3	36	
Size 4	24	

Data presented as mean (SD); median (IQR) for continuous data, and actual numbers (counts) for nominal data. Total participants, *n*=60. SD=Standard deviation, IQR=Interquartile range, ASA=American Society of Anesthesiologists, BMI=Body mass index

analysis between pairs of $ETCO_2$ was done by paired-sample, two-sided, Wilcoxon signed-rank test with continuity correction [Tables 2 and 3]. Cochran's Q test comparing counts of audible leak of airway gases in neutral, flexion, extension, left flexion, right flexion, left rotation, and right rotation positions showed a statistically significant difference ($P < 0.05$). *Post hoc* pair-wise analysis was done with McNemar test. Cochran's Q test comparing counts of visible displacement of i-gel® in neutral, flexion, extension, left flexion, right flexion, left rotation, and right rotation positions showed a statistically significant difference ($P < 0.05$). *Post hoc* pair-wise analysis was done with McNemar test [Tables 2 and 4]. We did not encounter any serious adverse events such as oxygen desaturation, loss of airway patency, pulmonary aspiration, or airway trauma in any of our patients.

Discussion

In this prospective, randomized crossover study, we compared the ventilatory performance of the i-gel® in neutral position and six different passive movements of head and neck, in spontaneous breathing patients on pressure support ventilation with PEEP under general anesthesia. Inhalation general anesthesia in spontaneously breathing patients on pressure support ventilation with PEEP with protected airway is a popular anesthetic technique for a vast number of patients undergoing limb surgeries, superficial surgeries of the torso, gynecological surgeries, and endoscopic-urology surgeries. The effect of passive head-and-neck movement on the performance of i-gel® SAD in spontaneously breathing anesthetized adults on pressure support ventilation with PEEP has not been studied previously.

Park *et al*.[2] evaluated oropharyngeal leak pressure (OPLP) and cuff pressure of three SADs, namely ProSeal™ laryngeal mask airway (PLMA), LTS, and CobraPLA™, in different head-and-neck positions in 139 adult patients. Lower OPLP results in leak of airway gases and deterioration of ventilatory performance of the SAD. These authors observed that none of these three SADs was free from the potential for airway compromise with head-and-neck movement.

Shin *et al*.[3] investigated the usefulness of the i-gel® compared with the cLMA and pLMA in anesthetized, paralyzed patients. They concluded that i-gel® may have a similar airway sealing to that of pLMA, higher than that of cLMA, and is not associated with adverse events. They proposed that i-gel® might be an effective alternative as an SAD. However, this study did not evaluate the effects of head-and-neck movements on the performance of the SADs.

Sanuki *et al*.[4] studied twenty anesthetized-paralyzed patients with airway maintained with i-gel®. OPLP and ventilation scores were measured with the head and neck in the neutral position, flexed, extended, or rotated to the right. Ventilation was scored from 0 to 3 based on three criteria (no leakage with an airway pressure of 15 cmH_2O or 1.5 kPa, bilateral chest

Table 2: Performance of i-gel® in different positions of head and neck under inhalation general anesthesia with spontaneous breathing on pressure support ventilation plus positive end-expiratory pressure

Parameter	Median (IQR)						
	Neutral	Flexion	Extension	Left flexion	Right flexion	Left rotation	Right rotation
Exhaled minute volume (L)	5.0 (1.5)	5.0 (1.5)	4.6 (1.4)	4.9 (1.6)	4.9 (1.6)	4.9 (1.6)	4.8 (1.6)
$ETCO_2$							
mmHg	36 (2.0)	36 (2.0)	39 (3.3)	38 (2.3)	38 (2.3)	37 (2.0)	38 (2.3)
kPa	4.8 (0.3)	4.8 (0.3)	5.2 (0.4)	5.1 (0.3)	5.1 (0.3)	4.9 (0.3)	5.1 (0.3)
Peak airway pressure							
cmH_2O	16 (4)	15 (5)	14 (4)	14 (4)	14 (4)	15 (5)	14 (4)
kPa	1.6 (0.4)	1.5 (0.5)	1.4 (0.4)	1.4 (0.4)	1.4 (0.4)	1.5 (0.5)	1.4 (0.4)
Pressure support							
cmH_2O	11 (5)	11 (5)	11 (5)	11 (5)	11 (5)	11 (5)	11 (5)
kPa	1.1 (0.5)	1.1 (0.5)	1.1 (0.5)	1.1 (0.5)	1.1 (0.5)	1.1 (0.5)	1.1 (0.5)
PEEP							
cmH_2O	5 (2)	5 (2)	5 (2)	5 (2)	5 (2)	5 (2)	5 (2)
kPa	0.5 (0.2)	0.5 (0.2)	0.5 (0.2)	0.5 (0.2)	0.5 (0.2)	0.5 (0.2)	0.5 (0.2)
SpO_2 (%)	100 (0)	100 (0)	99 (0)	99 (0)	99 (0)	99 (0)	99 (0)
Audible leak of airway gases (no/yes)							
No	58	57	16	22	23	55	53
Yes	2	3	44	38	37	5	7
Visible displacement of i-gel® (no/yes)							
No	60	58	17	38	40	55	54
Yes	0	2	43	22	20	5	6

Continuous data were subjected to Shapiro-Wilk test of normality (P<0.05 for all), and found to be nonnormally distributed. Continuous data presented as median and IQR. Nominal data presented as actual numbers (counts). IQR=Interquartile range, PEEP=Positive end-expiratory pressure, $ETCO_2$=End-tidal carbon dioxide

Table 3: Comparison of medians of exhaled minute volume in neutral, flexion, extension, left flexion, right flexion, left rotation, and right rotation positions

	P					
	Neutral versus flexion	Neutral versus extension	Neutral versus left flexion	Neutral versus right flexion	Neutral versus left rotation	Neutral versus right rotation
Exhaled minute volume	0.642	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*
$ETCO_2$	0.784	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*

*P<0.05 was considered statistically significant for paired-sample, two-sided, Wilcoxon signed-rank test with continuity correction. $ETCO_2$=End-tidal carbon dioxide

Table 4: Audible air leak and visible displacement of i-gel® in neutral, flexion, extension, left flexion, right flexion, left rotation, and right rotation positions

	P					
	Neutral versus flexion	Neutral versus extension	Neutral versus left flexion	Neutral versus right flexion	Neutral versus left rotation	Neutral versus right rotation
Audible air leak	0.564	<0.001*	<0.001*	<0.001*	0.317	0.095
Visible displacement of i-gel®	0.174	<0.001*	<0.001*	<0.001*	0.033*	0.020*

*P<0.05 was considered statistically significant for *post hoc* pair-wise analysis with McNemar test

excursion, and a square wave capnogram; each item scoring 0 or 1 point). The authors observed that compared with the neutral position, OPLP was significantly higher with flexion and lower with extension, but similar with rotation. However, flexion of the head and neck adversely affected the ventilation score compared with the neutral position.

Mishra *et al*.[5] conducted a study to assess and compare the effect of head-and-neck position on OPLP, fiberoptic view of glottis, ventilation scores, delivered tidal volumes, and $ETCO_2$ in all positions, between ProSeal LMA and the i-gel® under general anesthesia in sixty anesthetized-paralyzed adult patients. They found that in both groups, compared with neutral position, those with OPLP were significantly higher with flexion and lower with extension but similar with the rotation of head and neck. The authors observed that effective ventilation can be done with both ProSeal LMA and i-gel® with head in movement from neutral to full range of passive flexion, extension, and left lateral rotation.

Jain *et al*.[6] studied thirty anesthetized-paralyzed children with airway maintained with i-gel®. OPLP in neutral, maximum flexion, and maximum extension was the primary outcome. The authors observed that the OPLP was significantly higher in flexion and lower in extension in comparison to the neutral position, fiberoptic view in flexion was worse compared to neutral position, and the ventilation score was poorer and peak inspiratory pressures were higher in flexion compared to the neutral position.

Gupta *et al*.[7] studied sixty spontaneously breathing anesthetized children, thirty each in i-gel and LMA-Supreme group. They reported that head-and-neck flexion caused a significant increase in OPLP in both i-gel and LMA-Supreme groups.

Banerjee *et al*.[8] studied seventy anesthetized-paralyzed children who were randomly assigned to receive PLMA or I-gel®™ for airway management. Higher peak pressures and lower exhaled tidal volume in maximum flexion of the head and neck while ventilating with i-gel® were observed by these authors.

Kim *et al*.[9] did a systematic review and meta-analysis of 17 prospective studies (including five studies with i-gel®), which aimed to elucidate the effect of changes in head-and-neck position on the performance of SADs. The authors concluded that the reduced OPLP in the extended head-and-neck position was not associated with impaired ventilation except with the air-Q self-pressurizing airway. This meta-analysis apparently suggested that the flexed head-and-neck position significantly improves airway sealing (reduced leak of airway gases) but adversely affects ventilation and the fiberoptic view with most SADs. On the other hand, extension appeared to significantly reduce the airway sealing (increased leak of airway gases), and it did not affect ventilation or the fiberoptic view. Head-and-neck rotation did not appear to significantly affect SAD performance. However, this meta-analysis had an important drawback – the results of the original studies included in the meta-analysis indicate moderate-to-high levels of heterogeneity, and thus no conclusive evidence can be established.

Kim *et al*.[10] studied fifty anesthetized-paralyzed female patients with air-Q SP SAD *in situ* on volume-controlled ventilation. This study found that ventilation was not adversely affected in the rotated or flexed head-and-neck positions, whereas extension negatively influenced ventilation.

Ideally, an SAD should have a sufficiently high OPLP to allow positive pressure ventilation even with different head-and-neck positions. Increased OPLP implies better seal between the SAD and the pharyngeal wall. If OPLP increases with a particular head-and-neck position, it is likely to improve the ventilatory

performance of the SAD, unless that particular head-and-neck position causes displacement of the SAD to cause partial or total airway obstruction. Although fiberoptic scoring system is generally used to assess proper alignment of SAD with the laryngeal inlet, it does not necessarily translate into assured ventilatory performance. In fact, ventilatory performance of SAD can deteriorate due to lowering of OPLP (leak between SAD and pharyngeal wall), despite proper alignment of SAD with the laryngeal inlet. Effective seal between the SAD and pharyngeal wall is an important determinant of ventilatory performance of SAD. Further, ventilatory performance also depends on the lung compliance, airflow resistance, and mode of ventilation. Hence, it is inappropriate to draw conclusions about the performance of SAD in different head-and-neck positions using fiberoptic scoring system alone. We did not measure OPLP, as it is not safe to measure OPLP in spontaneously breathing patients under general anesthesia by subjecting them to increasing levels of CPAP above 20 cmH_2O or 2 kPa (the rated leak pressure of second-generation SAD like i-gel® is about 30 cmH_2O or 3 kPa). In our study, none of the patients had deterioration of SpO_2 although exhaled minute ventilation dropped along with audible leak of airway gases in certain head-and-neck positions. This might be due to the fact these patients were receiving 50% FiO_2 and PEEP, which possibly maintained satisfactory oxygenation despite decrease in exhaled minute ventilation over short period (after change of head-and-neck position). In addition, in spontaneously breathing patients, hypoventilation causing elevation of $ETCO_2$ triggers the respiratory center to increase respiratory rate and partly correct the hypoventilation. However, prolonged periods of abnormal head-and-neck position can cause cumulative decline in ventilatory performance of the i-gel® despite increased spontaneous respiratory rate. From our study [Tables 2-4], it is apparent that deterioration of minute ventilation is associated with lower airway pressures, audible leak of airway gases, and visible displacement of the i-gel®, in extension and lateral flexion of head and neck. However, our study was not designed to determine the causes and mechanism of deterioration of minute ventilation in these particular positions of head and neck.

Prior study[11] suggests that the pharyngeal length is increased upon extension of head and neck, possibly due to the elevation of the hyoid and the larynx, with flexion having the opposite effect. If the average internal diameter of the pharynx is relatively fixed, extension is likely to increase the internal volume of the pharynx, while flexion reduces the internal volume of the pharynx. With a given size of i-gel® in a given patient, this increased pharyngeal volume is likely to weaken the seal between the pharyngeal wall and the i-gel®, increasing the likelihood of leak and deterioration of ventilatory performance, while flexion is likely to have the opposite effect.

Walsh *et al*.[12] showed that, compared to the neutral posture, head flexion increases and head extension decreases the propensity for the pharynx to collapse in spontaneously breathing and anesthetized patients, while rotation appears not to have any effect. This decreased propensity of the upper airway to collapse is likely to reduce the conformity (fit) of the i-gel® with the pharynx, thereby increasing the chance of leak of airway gases and deteriorating the ventilatory performance of the i-gel®. On the other hand, normal or increased propensity of pharynx (neutral position, flexed position) to collapse under anesthesia is likely to improve the conformity (fit) of the i-gel® with the pharynx, thereby reducing the chance of leak of airway gases and maintaining ventilatory performance of the i-gel®.

Our results are in agreement with that of Park *et al*.[2] and Kim *et al*.[10] that the head-and-neck extension causes deterioration of ventilatory performance of second-generation SAD. Our results are in disagreement with that of the studies[4,5] on anesthetized-paralyzed adults, and the studies[6-8] on children with i-gel®. The functional anatomy of pharyngeal mucosa and muscles and lung dynamics are quite different in mechanically ventilated anesthetized-paralyzed adults or children from that of adults on spontaneous breathing on pressure support with PEEP (our study population). This might explain the disagreement of our results with these studies.[4-8]

Our study has some limitations. First, we studied the performance of size 3 and size 4 i-gel® only in various head-and-neck positions. Our results cannot be extrapolated to patients in whom other sizes of i-gel® SAD are used: overweight or obese adults, children, and infants. Second, our study was not designed to establish the causes and mechanism of variation of ventilatory performance of i-gel® in various head-and-neck positions. Magnetic resonance imaging studies in anesthetized patients with i-gel® *in situ* are needed to establish the causal relationship of various factors and underlying mechanism that determine the ventilatory performance of the i-gel® SAD in various head-and-neck positions.

Conclusions

Ventilatory performance of the i-gel® deteriorates upon extension, right or left lateral flexion, and right or left rotation of the head and neck in spontaneously breathing patients under general anesthesia on pressure support ventilation with PEEP. The i-gel® tends to preserve its ventilatory performance during passive flexion of the head and neck. During procedures under general anesthesia, that require sustained change of position of head and neck from neutral position, patient's airway should preferably be secured by tracheal intubation, instead of i-gel®.

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Conflicts of interest

There are no conflicts of interest.

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